

Sensor-Based Weather and Regional Modeling Technology (SWARM)

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The objective of this project was to define systems issues and identify key technologies required for a novel concept to deploy a "swarm" of micro-sensors for measurement of weather parameters. The technologies that were identified are broad-based and are now being applied to several areas, including the cargo container security problem.

There are both military and civilian interests in improved prediction of weather. The DoD requires accurate three-to five-day knowledge of weather conditions in regional battlefields or surveillance areas. However, much of climate research has focused on satellite surveillance, which does not provide altitude profiles of data that is needed for most models.

Based on a concept proposed by E. Teller, deployment of thousands, or millions, of micro-balloons containing low-power sensors, intelligence, and communications distributed in a constellation of free-floating, neutrally-buoyant transponders would provide atmospheric data that can be used to initialize future high-resolution numerical weather-prediction models. This concept can be made feasible by microtechnology research at LLNL and U. C. Berkeley, but there are formidable systems issues to address.

For weather forecasting, the required spatial resolution (globally) is on the order of 10 km, and vertical resolutions on the order of 0.5 km. The concept involves deploying small (10-cm-diameter nominal) balloons equipped with advanced sensors, on-board GPS, communications, and simple networking capability—balloons that can be placed at various altitudes (up to 20 km) and locations (see figure). The observed quantities we are measuring are wind (vector), temperature, pressure, humidity, and, later, water content (phase) and chemical concentrations. For every group of (say, 100) sensors deployed, there would be a somewhat

larger package to relay data to a satellite or ground station for forecast/analysis processing. Simple integrated sensor and line-of-sight communications packages of this size have already been demonstrated.

Several engineering issues associated with the design of the balloon package were addressed. One is the communications link, which must have extremely long range (preferably tens to hundreds of kilometers). A possible solution is active reflectance with a thin metal dipole antenna that acts as a "tail" for keeping the balloon upright. A higher-power ground station senses the on-board switching capacitor that would modulate the return signals (see table for communications options). Simulations show that these systems could be deployed from hundreds of kilometers and require very low on-board power (μ A).

Another issue is the inclusion of GPS in a small package along with the sensors and the processing element. On-board power that meets the needs of all subsystems is critical; currently we are using an integrated battery or fuel cell, coupled with solar backup power on top of the balloon. Finally, a means of attaining neutral buoyancy at various altitudes, and providing simple altitude control, will be a requirement.

Small sensor packages for detection of nuclear, chemical, or biological threats (as well as rudimentary imaging) are also under development using similar networking and communications scenarios.



Comparison of Communications Options for Micro-Balloons.

Option	BW ¹ (bps)	Range (km)	Power ² (W)	Weight ³ (g)	GPS ⁴ req'd?	Relative cost ⁵
Cell phone	1000	10	.3	20	Y	Med.
Satellite phone	1000	400	.8-1	100	Y	High
Two-way pager	10	20	.05	15	Y	Med.
JSTARS/tags	1000	250	10 ⁻⁴	1	N	Low
Dedicated radar & tags	10,000	500	10 ⁻⁴	1	N	Low

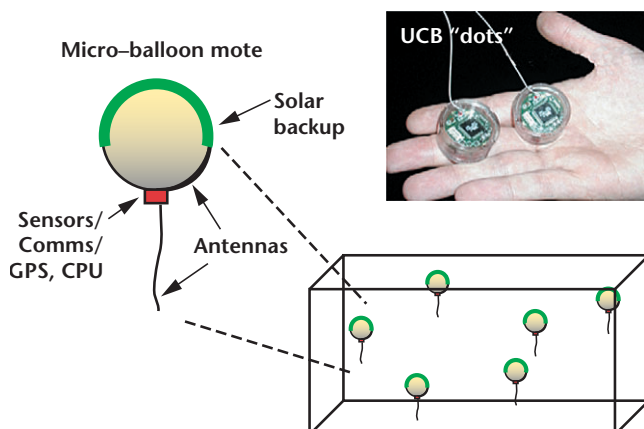
1. Bandwidth (BW) is "uplink" speed from sensor to base station. Downlink (sensor data transfer) speeds must be faster than uplink (control) speeds.

2. Power is the estimated power draw for the full communications system from antenna through to microprocessor, while communicating at the maximum bit rate. All handshaking protocols are handled by this subsystem. Any of these systems could be controlled to only communicate at specific intervals, thereby reducing power requirements.

3. Weight is estimated for the communications subsystem alone, not including power supply or other subsystem.

4. GPS is required for systems that have no other means of localizing the individual balloons. Radar-based systems will determine location of each platform, but at lower resolution than GPS.

5. Relative cost estimates are for the sensor communications only. Base station costs will be considered separately.



Micro-balloon sensor package.